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Sustainable Lighting

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01

Editorial

“Will you please stop building the way you build!”
Frei Otto, 1977

The earliest reference to “sustained use” in print appears in a book by Carl von Carlowitz published in 1713. The author’s thoughts were on the need to make economical use of forestry resources – to cut down only as much timber as could be grown to replace it. Around 300 years later, the Google search engine lists more than 40 million hits for the word “sustainability”. The issue has become a priority for our society in recent decades. How do we secure the future for future generations? How do we manage our environment so that natural resources are conserved, economically acceptable solutions found and sustainable social development ensured?

For the German Sustainable Building Council – DGNB – the word sustainability sums up our core objectives, which include committing the whole of society to taking responsibility for present problems such as climate change and resource depletion and not leaving them for future generations to deal with. Our concept of sustainability goes beyond the traditional three-pillar model that considers ecology, economy and user comfort. The design and realisation of sustainable buildings and urban districts also takes account of functional and technological aspects, processes and even location.

We want to sensitise and win over the public to the idea that sustainable building will be taken for granted in the future and we want to show how the design and construction process can be managed to achieve that. Every resident and every building can help promote sustainability. Light – both natural and artificial – plays an important role in defining the quality of architecture and the way it is perceived. Controlling the “intangible” qualities of light in indoor and outdoor spaces presents a special challenge for designers. Spatial impact aside, high-quality lighting with efficient light sources and intelligent technology is an important criterion for successful certification. This is clearly shown by the many buildings and urban developments that have been awarded the DGNB seal of approval in recent years.

The DGNB acknowledges the importance of light and its relevance for sustainable building, amongst other things by introducing the criteria profile “Visual Comfort”. At universities, the basics of light and the integration of lighting concepts into architectural designs are important subject areas of bachelor’s and master’s degree courses.

Students are keenly interested in the phenomenon of light, so where lighting is harnessed to enhance quality of space, sustainability naturally becomes an architectural issue.

I therefore welcome this new licht.wissen 20, which provides important information and practical examples of sustainable lighting for the design and construction process.

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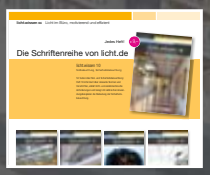


02

Aspects of sustainable lighting

Environmental	Economic	Social
Sustainability		
nature conservation climate protection resource conservation	capital return on investment conservation of value	health safety quality of life
Sustainable lighting		
energy efficiency avoidance of light pollution emission control recycling	low power costs long life low maintenance improved productivity through better light	high quality of light high user comfort greater sense of wellbeing lighting tailored to requirements

03

Green light for the future

In the past, sustainability mainly meant protecting the environment. But action that is really sustainable also takes account of economic and social issues. Modern lighting technology makes a valuable contribution here.

Sustainable action is as old as mankind. In the daily fight for survival, stone-age man in Africa filled ostrich eggs with water and buried them for when times were hard. In antiquity, highly skilled architects and master-builders sought to create structures that would last forever. Even today, pyramids and Roman aqueducts withstand natural disasters and erosive forces and are good examples of sustainable architecture.

But the human race has not always managed its affairs in a sustainable manner. Wood was one of the first natural resources to fall victim to the advance of civilisation, as swathes of barren terrain around the Mediterranean still testify today. Despite that fact – or perhaps because of it – it is to forestry that we owe our modern concept of sustainability. A Saxon mining administrator called Hans Carl von Carlowitz coined the phrase “sustained use” (“nachhaltende Nutzung”) in his book “Sylvicultura oeconomica” published in 1713. He proposed a simple rule: cut down only as much timber as can be grown to replace it – the blueprint for a self-sustaining economic system.

Environmental issues are still central to the sustainability debate today. Economic growth after the Second World War was achieved at the cost of massive environmental damage. Problems such as water pollution and forest dieback became increasingly urgent, until finally they were addressed by politicians at international level. The UN Conference on the Human Environment held in Stockholm in 1972 marked the birth of international environment policy.

Three pillars:
environment, economy, social

It quickly became clear that sustainability is not confined to environmental issues alone. Today, the three-pillar model of sustainability, focusing on environment, economy and the social dimension, is widely accepted (Source: Brundtland Report – Report of the UN World Commission on Environment and Development). In 1992, at the first major sustainability conference in Rio, an international partnership for sustainable development was created defining global sustainability goals and measures – from poverty reduction to species conservation.

Since then, sustainability has been successfully conveyed from the abstract political level to the heart of society. Initiatives such as the UN Carbon Discloser Project (*www.cdproject.net*) drive sustainable action forward. In Germany, guidance for national sustainability strategy has been provided since 2001 by the German Council for Sustainable Development (www.nachhaltigkeitsrat.de).

Apart from politicians and non-governmental organisations, many companies are also committed to the sustainability cause: economical use of resources, personnel protection and development, transparency and integrity are now inherent components of corporate social responsibility. Products need to meet stringent criteria in terms of environmental friendliness and cost-benefit efficiency.

The impact of climate change
on the debate

The greenhouse effect and climate change have injected a new dynamism into the international debate on sustainability. At the Kyoto Conference in 1997, many industrial countries committed for the first time to take action specifically designed to mitigate climate change. Even though individual actors such as Canada subsequently withdrew from the Kyoto Protocol, its provisions are binding for most parties to the convention through to 2020.

The EU has become a pioneer in climate protection. By 2020, it intends to reduce energy consumption by 20 percent compared to 1990 levels, which will cut carbon emissions by 780 million metric tons. Helping it work towards that target are

[02] Modern lighting technology helps meet human needs and can contribute a great deal to sustainable development.

[03] Sustainable lighting is environmentally benign, makes economic sense and promotes a sense of wellbeing by delivering light tailored to needs.

04

resolutions such as Ecodesign Directive 2009/125/EC, which sets out requirements for energy related products. It provides a basis, for example, for eliminating inefficient light sources from the European market.

With this heightened commitment to climate protection, energy management has become a core issue of sustainability. In Germany, new impetus has been given to this development by the phasing-out of nuclear power and the ambition to transform the country's energy sector by cutting fossil fuel consumption and developing regenerative energy sources.

Modern lighting technology contributes to sustainability

One of the biggest resources, however, is energy efficiency – because the best alternative source of energy is *unused* energy. The figures speak for themselves: according to the German Electrical and Electronic Manufacturers' Association (ZVEI), electricity consumption in Germany could be reduced by 80 billion kilowatt/hours a year by improving the efficiency of electrical equipment and automated processes alone. The technology needed to do so is already available. The government has recognised this opportunity and supports switchover projects, e.g. by offering grants for LED based municipal lighting installations.

The investment is worthwhile because modern lighting technology can make an important contribution to sustainable development. Efficient light sources, optimised luminaires and electronic control systems conserve natural resources, are largely recyclable and reduce costs. They also provide better light for the performance of visual tasks and promote wellbeing.

With lighting technology, the entire lighting industry has joined the vanguard of the sustainability movement. Self-imposed sustainability targets are regularly documented and monitored in reports.

- **Environment:** The lighting sector plays an important role in the drive to meet the climate targets of the Kyoto Protocol. The development of resource-saving lighting

05

technology is an integral part of its sustainability strategy. LEDs, ballasts and other “green” products that are sustainably manufactured and save energy figure prominently in the portfolio of many members of the ZVEI Lighting Division. As for production operations, many companies comply with the environmental requirements contained in international standards such as ISO 14001.

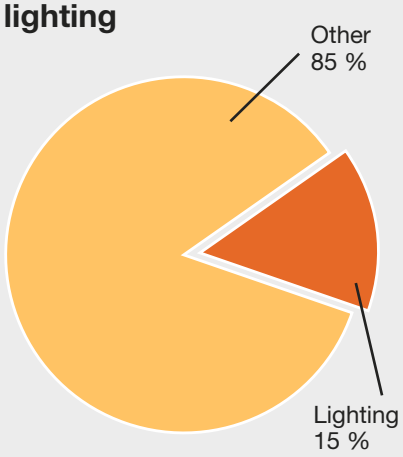
- **Corporate Governance:** Written guidelines ensure that companies act ethically and behave responsibly towards employees and customers. This includes ensuring and monitoring compliance with health and safety rules.

- **Corporate Social Responsibility (CSR):** The lighting sector seeks social dialogue – with customers at trade fairs or local service points, with scientists at conferences and research projects. It furnishes expertise in standards committees and associations. Companies take responsibility for their employees by investing in health and safety management and further training.

- **Research and development:** In laboratories and development departments, lighting manufacturers work on even more efficient, even better-performing technologies, thus translating the idea of sustainability into long-lasting user-friendly products that make sparing use of resources.

Many manufacturers in the lighting industry comply with international corporate standards in their daily operations. Those standards include ISO 9001 for quality management as well as ISO 14001 and 50001 for environmental and energy management. The manufacturers’ commitment benefits everyone involved: for the consumer, for instance, ISO 9001 certification provides a guarantee of high-quality products; companies profit from guidelines that lower error rates and costs – and compliance with ISO 50001 and ISO 14001 reduces the pressure on the environment and climate.

Percentage of global electricity consumption attributable to lighting



06 Source: International Energy Agency © licht.de

[04 + 05] The development of resource-saving lighting technology is an integral part of the lighting industry’s sustainability strategy.

[06] According to the International Energy Agency/ United Nations Environment Programme (IEA/UNEP, spring 2014), lighting accounts for 15 percent of global electricity consumption.

Light for greater sustainability

Modern light sources such as LEDs require little energy and thus ease the pressure on the climate system. But green lighting technology can do even more. It achieves impressive eco-balances, cuts costs and makes for a better quality of life.

According to figures published by the International Energy Agency (IEA), lighting is responsible for around 15 percent of global electricity consumption and nearly five percent of global greenhouse gas emissions.

At the same time, energy consumption is significantly higher than it needs to be. According to the European Commission Green Paper "Lighting the Future" (2011), around 75 percent of all lighting installations in Europe are more than 25 years old. So the saving potentials are high. In 2009, the ZVEI calculated that around 1.4 million metric tons of carbon dioxide emissions could be avoided and costs of around 400 million euros saved on street lighting alone. The figures show that efficient lighting technology can make a real difference in mitigating climate change. But sustainable lighting can do even more:

- **LEDs** not only save energy; they combine high lighting quality with longevity. In outdoor lighting, they avoid light pollution and do not interfere with nocturnal insects. LED technology also has an impressive eco-balance. More than 90 percent of an LED light source's total carbon footprint is generated in operation; only two percent is required for its manufacture. LEDs offer many advantages, which is why the McKinsey study "Lighting the way" (2011) forecasts that LEDs will account for 70 percent of light source sales by 2020.
- **Luminaires** with a high light output ratio and a long life save electricity and maintenance costs. Reduced luminaire dimensions and recyclable materials such as aluminium and glass conserve valuable resources. The recyclability of luminaires is taken into account right at the product development stage.
- **Lighting management,** combined with electronic operating devices, permits variable lighting scenes, perfect coordination with daylight, presence control and thus greater lighting comfort. Electronic control offers the greatest savings potential. With it, energy consumption can be reduced by as much as 70 percent.
- **Raw materials** need to be used carefully so that they can later be reclaimed for re use. In the case of LEDs, this applies to the electronics; with fluorescent lamps, it applies to rare earths and mercury and with luminaires, aluminium, iron, plastics and glass. The lighting industry favours the use of recyclable or reclaimable materials and takes maximum care to ensure that harmful substances are avoided in strict accordance with the regulations in place.
- **Recycling** systems ensure that components such as glass or metal can be reused at the end of a product's life cycle.
- **Professional lighting design** guarantees that lighting is tailored to needs. In offices and manufacturing premises, standard-compliant lighting makes for optimal working conditions and thus helps create added value. Technical stipulations are taken into account; so are users' needs and requirements.
- **Sustainably designed light** meets human needs. It ensures safety on roads and in public places, it safeguards our health when we are at work and play, it impacts positively on our sense of well-being and it thus makes for a better quality of life.

[07] Efficient lighting makes an important contribution to protecting the environment.

Literature on the subject

Hans Carl von Carlowitz: "Sylvicultura oeconomica", 1713.

Brundlandt Report of the UN World Commission on Environment and Development: "Our common future", 1987.

McKinsey Report: "Lighting the way", 2011.

07

08

Light for liveable cities

Cities worldwide are plagued by a whole range of problems: air pollution, road congestion, social tensions. Modern lighting eases the pressure on carbon balances and municipal budgets. But above all it helps make for a better quality of life for residents.

Astronauts at the International Space Station (ISS) are witnesses of a global trend. At night and when visibility is good, they see the world's cities as patches of light in the dark expanse of uninhabited terrain. And those patches are growing, as the dark areas shrink – a sign of advancing urbanisation. In 2012, 71 percent of Europe's population lived in an urban environment (Source: Deutsche Stiftung Weltbevölkerung); the global figure was 51 percent – and rising.

The trend towards urbanisation presents many problems: air pollution, water consumption, accumulation of waste. And the negative environmental side effects are accompanied by economic and social problems such as shortage of housing and poverty. One solution for sustainable urban development is presented by "Green City" concepts. At international and local level, politicians, scientists and business work on plans designed to keep urban growth within reasonable, stable limits.

Sustainable lighting for the urban environment

Modern lighting technology makes an important contribution towards sustainable urban development. Efficient, long-life light sources – such as LEDs – reduce energy consumption. Luminaires with optimised optical control elements and electronic lighting management also improve carbon balance and quality of light. Lower outgoings for maintenance make for greater cost efficiency.

Exterior lighting presents a major opportunity for urban areas to raise their profile as "green cities". "LED City" Königsfeld in the South West of Germany is a good example. The Baden-Württemberg spa town is a member of the Black Forest LED network (LED-Netzwerk Schwarzwald). From parks to residential areas, almost all of the town lighting has now been switched to LED. Replaceable modules guarantee that the LED technology used is always up to date. With modern control technology, energy consumption has been cut by 62 percent. The project has won the town the EU „Green-Light Award" (*www.eu-greenlight.org*).

LED technology and digital lighting control increasingly form the foundations of sustainable urban lighting. Apart from high efficiency, LEDs offer a number of other advantages: precise light control avoids undesirable light emissions, which can disrupt biorhythms and frequently give rise to complaints of light pollution. Another environmental plus of modern lighting is that it does not interfere with nocturnal insects. Studies show virtually zero response to the light of modern lamps or LEDs.

Light for a better quality of life

But sustainable urban lighting does more than protect the environment, help mitigate climate change and boost energy efficiency and cost effectiveness. As in the home, light plays an important role in the city as a

09

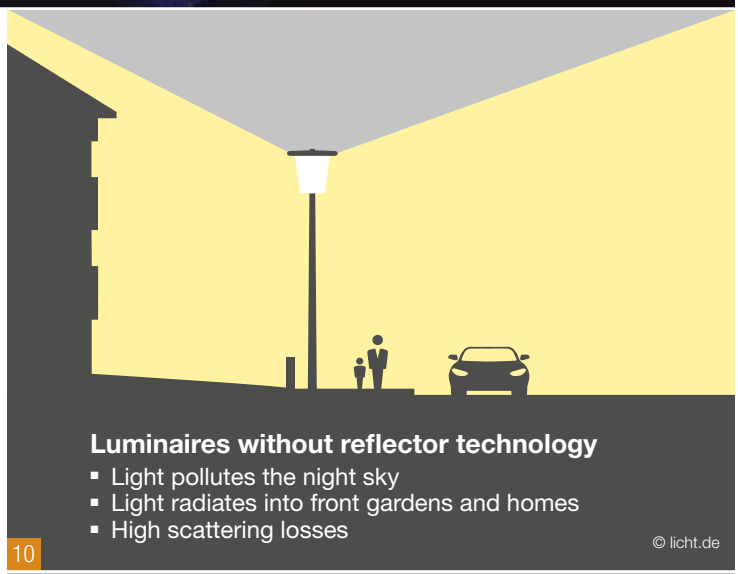
mood-setter – because lighting shapes the face of urban surroundings at night. It provides security, creates atmosphere and impacts crucially on local environment and quality of life. Some interesting figures were produced by a Forsa study in 2010. The researchers found that 97 percent of Germans consider their immediate environment to be an important factor in personal life. Ahead of salary and holidays, it only ranks second to health.

So one thing is clear: energy efficiency and cost effectiveness alone do not make for sustainable urban lighting. Lighting can only be described as sustainable if it improves quality of life in the urban environment and finds acceptance among the people living with it.

[08] Sustainable urban lighting is good for the environment and significantly helps improve security and quality of life.

[09] The patches of light on Earth are spreading: in 2012, 71 percent of people in Europe lived in an urban environment.

[10 +11] Energy-efficient light sources and luminaires casting precisely controlled light save energy, guard against “light smog” and do not interfere with nocturnal insects.



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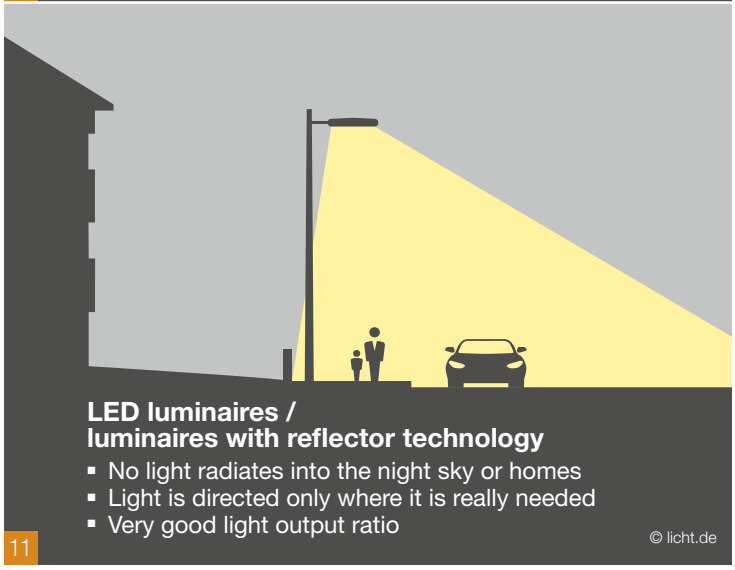


11

Light – building block of sustainable architecture

Across Europe, the term “green building” was coined to denote a building of energy efficient design. Today, it is being superseded by the expression “blue building”, which indicates a balanced sustainability concept: blue building conserves resources, is cost effective and offers a high degree of comfort for occupants. With high-quality lighting, building owners can score important points for certification.

Plants on facades, trees on the roof? Not all sustainable buildings take green building that literally. Even so, virtually no new building today can ignore the sustainability issue. To meet ever-stricter efficiency requirements and ensure long-term property value, more and more building owners are taking care to build sustainability into their plans.

Green building aims at reducing consumption of non-renewable energy, water and land. But sustainable building does more than just help the environment. Current sustainability concepts consider the triad of environment, economy and sociocultural aspects. This means that: cost, quality, comfort, accessibility and many other factors are taken into account in design and construction.

With high-quality lighting, builders can score a whole range of sustainability points:

- for protecting the environment and helping mitigate climate change – because efficient lighting technology keeps electricity consumption and carbon emissions low;
- for improving cost effectiveness – because energy-saving long-life light sources reduce power and maintenance costs;
- for enhancing user comfort – because good lighting ensures a high quality of light and an agreeable atmosphere.

Sustainability certificates

Builders and operators can show sustainability by securing certificates. This entails more work and additional cost. Nevertheless, certification is not just a moral asset; it has a real cash value. For example, it is an effective marketing tool for properties. Future-proof construction avoids loss of value for the owner. Certification goes hand in hand with careful planning and investment in sustainable technology, which often pay dividends in terms of greater cost efficiency.

A growing number of investors and building owners appreciate the benefits of certification. According to a Deutsche Hypothekenbank study done in 2012, the supply of certified buildings in Germany grew by 30 percent to around 500 properties in 2011.

One of the earliest green building certificates was the British BREEAM label launched in 1990. Internationally, the leading certification system is the LEED (Leadership in Energy and Environmental Design) developed by the U.S. Green Building Council. LEED points are spread over six categories, which include water efficiency and energy management.

In Germany, the quality seal of the German Sustainable Building Council (DGNB) has become an established form of certification. It has been awarded since 2008, in the grades “gold”, “silver” and “bronze”. DGNB certification is not just confined to private and public buildings; entire urban districts are also eligible. The table on the right shows the most important blue/green building certificates.

The DGNB has developed a system of six rating categories with a total of around 40 criteria. The categories are: environmental quality, economic quality, sociocultural and functional quality, technical quality, process quality and site quality. Lighting scores points in three different categories of the DGNB rating system.

Functional quality:

- User influence
- Lighting control
- Daylight availability
- Visual contact with outside
- Protection from glare (daylight and artificial lighting)
- Good colour rendering
- Exposure to sunlight

Environmental quality:

- Energy efficiency of lighting

Economic quality:

- Cost efficiency of lighting

Shining example: company head offices win DGNB gold

Efficient lighting technology alone does not guarantee a certificate. But good lighting can do a lot to help ensure successful certification. This is clearly evidenced by a case in Essen, where DGNB assessors rated the new head offices completed in 2010 for a long-established industrial concern. The new facility was strictly designed and constructed as a sustainable building complex.

400,000 centrally controlled lamellae permit optimal use of daylight. Illuminance in the offices is automatically adjusted by sensor-controlled standalone luminaires that take account of natural incident daylight. Presence detectors activate the artificial lighting only when it is actually needed. The result is high user comfort and minimum energy consumption. The luminaires are connected via an interface to the building management system, so the lighting can be centrally controlled along with other systems such as heating, ventilation and cooling.

The total primary energy consumed by the buildings is 58 percent lower than statutory requirements. For the high sustainability standards achieved, the company head office complex was awarded a gold DGNB certificate.

[12] Systematically sustainable: the new headquarter complex for a long established industrial concern offers an agreeable working environment with lots of daylight and high-quality lighting. Along with other systems such as heating and ventilation, the lighting is centrally controlled by an integrated building management system. The building complex was awarded a gold DGNB certificate for the high sustainability standards achieved.

[13] Certificates confirm a building's sustainability. Owners profit from meticulous planning, sustainable technology and cost efficiency; they also avoid loss of value. The table lists various labels and the main lighting criteria for certification.

12

Label & sponsor	Country	since	Description	Main criteria	Lighting criteria*
LEED Leadership in Energy and Environmental Design	USA	1998	LEED is a label in international use. It is awarded in platinum, gold, silver and certified.	use of space, water efficiency, energy, materials and resources, indoor environmental quality, innovation, regional priority	light pollution reduction, energy efficiency, daylighting, visual contact with outdoors, user-friendly lighting control
BREEAM Building Research Establishment`s Environmental Assessment Method	UK	1990	BREEAM largely rates the environmental and social sustainability of buildings. The rating scale is as follows: Outstanding, Excellent, Very Good, Good and Pass.	management, health and wellbeing, energy, transport/access, water supply, materials, waste, use of space pollution, innovation	energy efficiency, daylighting, efficient user-friendly lighting control, glare protection, good colour rendering
DGNB Deutsche Gesellschaft für Nachhaltiges Bauen e.V.	Germany	2008	The DGNB certificate takes account of environmental, economic and social sustainability factors. Around 40 criteria are assessed. The rating grades are gold, silver and bronze.	environmental quality, economic quality, sociocultural/functional quality, technical quality, process quality (e.g. design/construction), site quality	energy efficiency, cost efficiency, daylighting, visual contact with outdoors, glare protection, good colour rendering, exposure to sunlight
Minergie Verein Minergie	Switzerland	1998	Minergie largely assesses buildings on the basis of energy consumption. Minergie Eco presents additional requirements in terms of health-promoting and environmentally sound construction.	building shell, efficient heating and ventilation, renewable energies	bright interior design, efficient light sources, luminaires with electronic ballasts, optimised luminaire reflectors, daylight management/presence detectors

*Only the main lighting criteria are shown. Full criteria catalogues, including standard requirements and limiting values for lighting, are available from the certifying organisations.

13

Sustainable value creation

Innovative lighting technology enhances the quality of a building. To harness its full potential, it is essential that those involved in the project interact effectively and that standards are observed over the full life cycle.

Sustainable lighting has to meet exacting standards: efficiency, longevity and high quality of light are important features. But they are not the only criteria. The materials used in light sources and luminaires should be largely recyclable and free of toxic substances. High user comfort is another requirement; so is easy maintenance.

To fulfil these criteria, the idea of sustainable lighting needs to be embraced throughout the value-added chain – from raw materials to distribution. But even that is no guarantee of sustainability. The potential of modern lighting technology can only be tapped fully if professional lighting design, installation and maintenance are parts of an integrative concept.

Processes
The realisation of a new building or refurbishment of an existing one is a long process (see fig. 14). It starts with the initial idea (project initialisation), continues with design work and invitations to tender and is far from over even after the construction work is completed. The building then has to be diligently operated and maintained and arrangements made for its disposal at the end of its life.

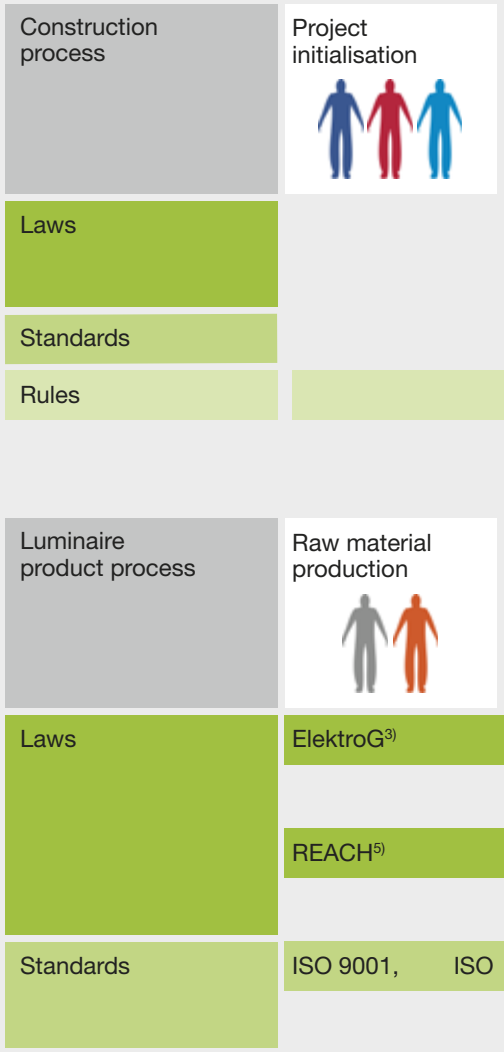
Lighting figures in a construction project from the beginning to the end of its life cycle. It features in all the planning and forms part of the tender package. Its installation is an important phase of completion. Efficient operation and easy maintenance keep costs low and ensure the economic efficiency of the building.

Actors
Sustainable lighting is achieved through the effective interaction of many actors. In the construction process, the building's owner, designer and operator define the requirements on which the design will be based. Then tenders are invited and contracts awarded, followed by installation and commissioning. What is also often essential at this stage is professional support by the manufacturers of the lighting products. Because of their special expertise, they also remain important partners for operation and maintenance.

Manufacturers focus on sustainability throughout the product process: they ensure that component suppliers observe key environmental standards and that products are designed with conservation of resources and avoidance of harmful materials in mind.

Standards
State regulations ensure that important sustainability targets are met, both in lighting and

Life cycle of lighting: processes,



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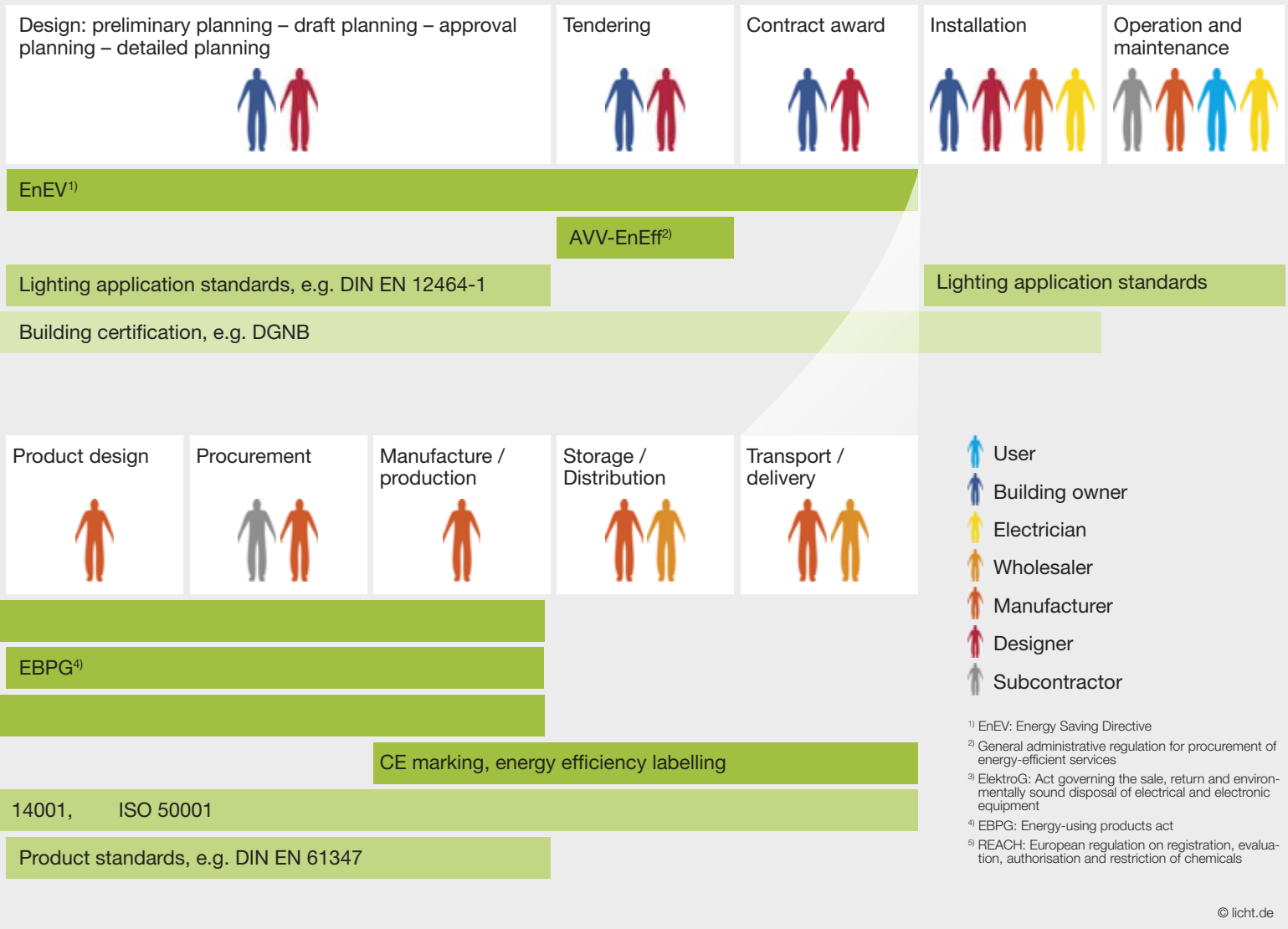
actors, standards



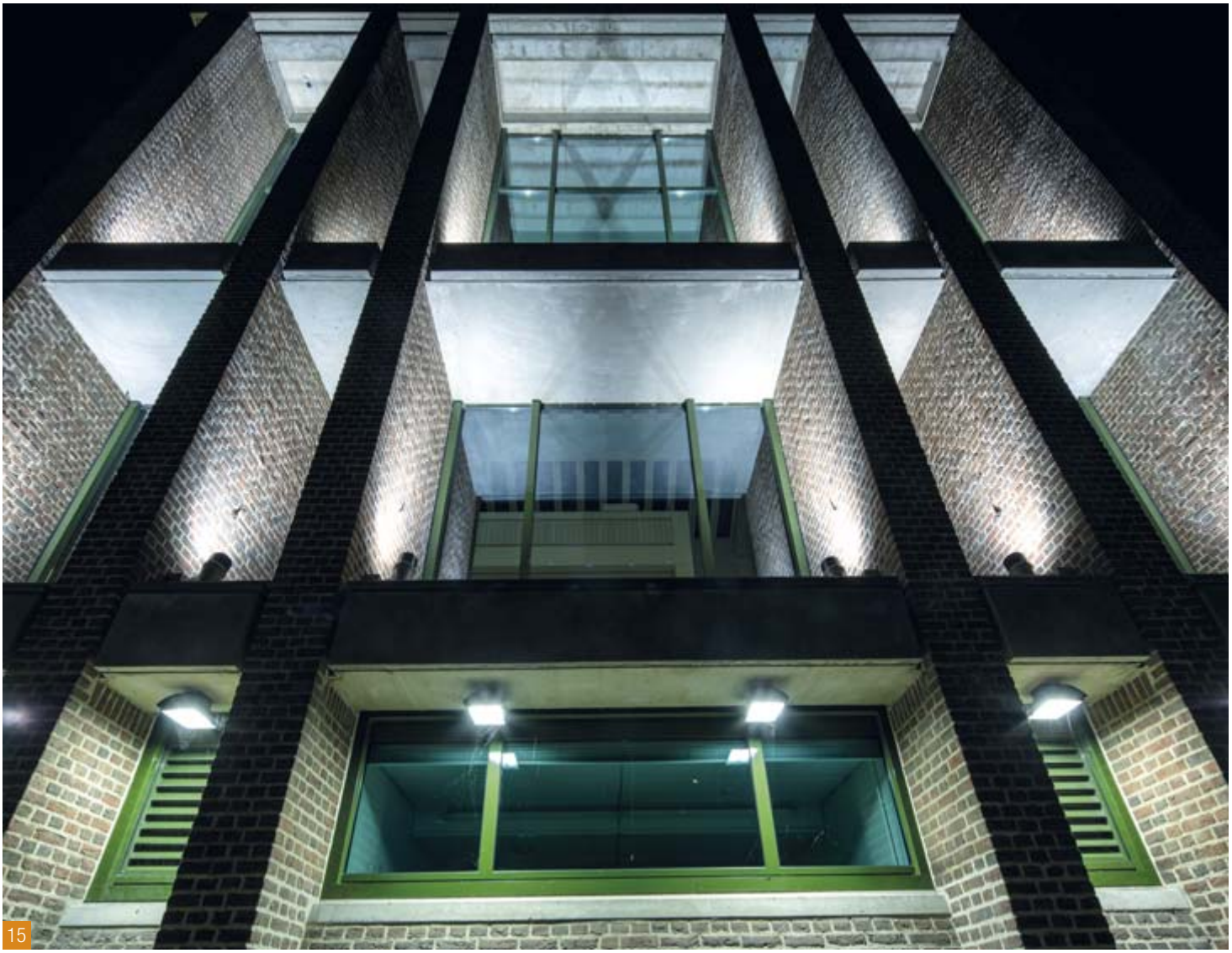
in the construction process. Take new buildings, for example. In Germany, the Energy Saving Directive (EnEV) implements various EU directives on building efficiency. Amongst other things, it stipulates that the primary energy demand of a non-residential building for lighting must be established at the preliminary design or refurbishment stage.

For lighting products such as lamps and luminaires, return and disposal standards are implemented by legislation such as the Electrical and Electronic Equipment Act (ElektroG) in Germany.

In addition to state regulations, manufacturers, designers and builders take account of standards that present high requirements in terms of lighting technology and lighting quality. At the product design stage, manufacturers observe lighting product standards such as DIN EN 61347. For lighting designers, crucial guidance is provided by the application requirements set out in standards such as DIN EN 12464-1 (for indoor work premises).

Statutory and voluntary standards offer advantages for everyone involved: for manufacturers, they create incentives for innovation; building owners save electricity as a result of high energy efficiency and occupants profit from high quality of light and user comfort.

Further up-to-the-minute information about standards and regulations can be found at *www.licht.de*.



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From raw material to disposal

Conservation of resources, avoidance of waste, re-use of materials – sustainability accompanies modern lighting through its entire life cycle. Special attention is paid to energy efficiency.

Power is consumed even before lights are switched on for the first time – in the course of their manufacture, for example, and during shipment to the dealer. And the energy counter still keeps on ticking at the end of a lamp's life too – because regardless of whether lighting hardware is disposed of or recycled, both processes require the use of more energy.

And the eco-balance can extended even further – right back to product design. Materials and other resources should be used sparingly in the manufacturing process and harmful substances reduced to a minimum. To assess the sustainability of a lighting installation over its entire life cycle, the costs incurred here also need to be considered.

Most companies in the lighting industry are aware of these circumstances and bear sustainability in mind from the outset. Production and packaging are designed to minimise waste and environmentally harmful substances. Water treatment and filter systems prevent harmful emissions. Modern logistics systems guarantee that the least possible energy is used to transport products to dealers and end consumers. The fact that many manufacturers are certified to ISO 14000 also indicates the high environmental standards that are generally demanded from ancillary suppliers.

Raising the recycling rate

European directive 2012/19/EU (WEEE) prescribes recycling for lighting. So even at

the design and construction stage, sustainability-minded manufacturers of luminaires, for example, have an eye on the end of their products' life. They give preference to the use of recyclable materials such as glass, steel or aluminium. Halogen-free wiring offers one opportunity to help raise the luminaire recycling rate. For lamps and LEDs, German manufacturers have created an extensive network of collection points through the recycling company Lightcycle Retourlogistik und Service GmbH.

That said, the amount of energy used for manufacturing processes, shipment and recycling is comparatively small. The operation of lighting installations accounts for more than 90 percent. So, electricity consumption is by far the most important factor in the energy balance – and the most important cost factor as well. It also determines how much climate-damaging carbon dioxide is emitted when a luminaire is in operation. Lighting industry and science are thus working hard to increase lighting's energy efficiency even more. The progress that has been made can be clearly seen from a comparison of conventional incandescent lamps with modern LED lamps (see fig. 17): while incandescent lamps have a primary energy input requirement of nearly 3,300 kilowatt-hours (kWh) per 25,000 operating hours, LED lamps consume only around 660 kWh.

Electronic lighting control taps additional savings potential, e.g. by automatically activating luminaires only when they are needed.

[15] LED facade luminaires deliver glancing light that accentuates the building at night and emphasises its architecture. LEDs are efficient and virtually maintenance free.

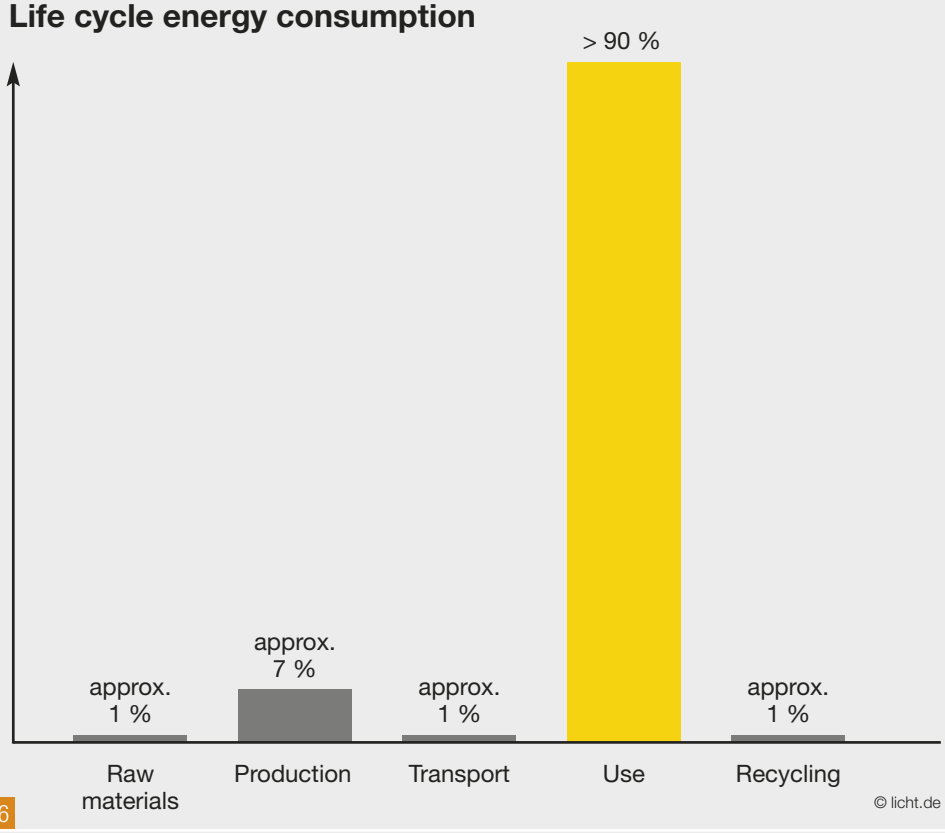
[16] More than 90 percent of the total energy consumed by a luminaire is consumed during operation. Efficient light sources thus offer high savings potential.

[17] Modern light sources are very efficient. LED and compact fluorescent lamps (CFLs) consume considerably less primary energy than conventional incandescent lamps.

Energy balance of light sources

Light sources do not only consume energy during the time they are in operation. For a full energy balance, their manufacture and transport, disposal and recycling also need to be taken into account. Life-cycle analyses establish the total primary energy consumed by a light source from cradle to grave. Total energy consumption can thus be compared. An example: an LED lamp requires significantly less primary energy than a comparable halogen lamp for the same light output (see fig.17).

Life cycle energy consumption



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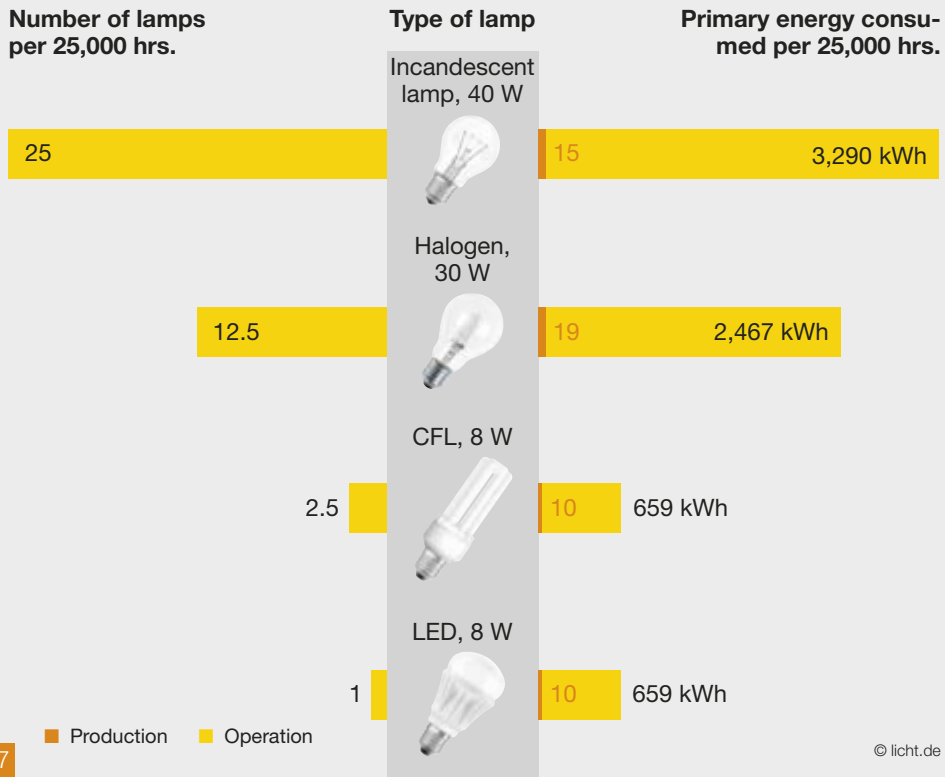
Comparison of light sources



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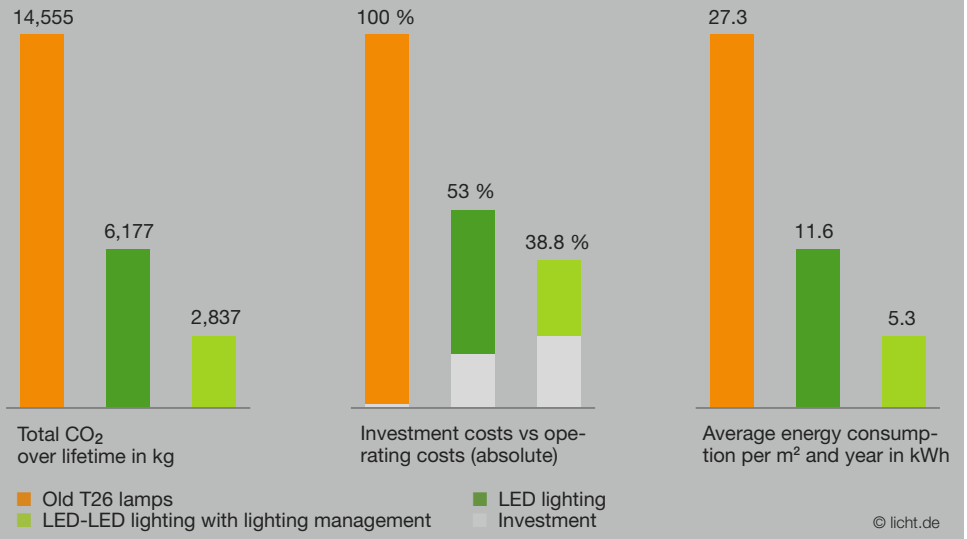
18

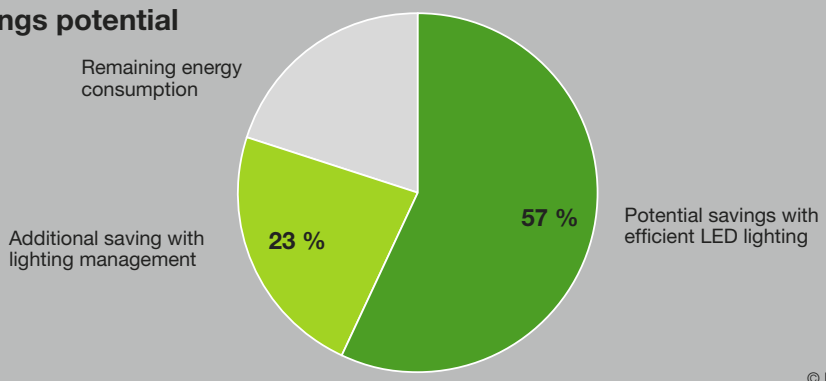
Practical example: LEDs for sustainable lighting

Energy consumption and maintenance account for around 85 percent of the cost of a lighting installation. Sustainable lighting keeps electricity and maintenance bills low while at the same time delivering more comfort and a better quality of light. How this works is shown by an application example: the original lighting provided for a classroom by diffuser luminaires and T26 fluorescent lamps was replaced by surface mounted LED luminaires as well as two LED wallwashers for board lighting. A daylight dependent control system and presence sensors automatically tailor the lighting to actual requirements and help save energy. The charts below show the distribution of maintenance, energy and acquisition costs of the new lighting installation over a 20-year period.

Energy consumption and costs



Savings potential



19

Investment recouped through savings

When the entire life cycle of a lighting installation is considered, it quickly becomes clear that investment in sustainable lighting pays dividends. Lower electricity and maintenance costs make up for the outlay on modern lighting technology. However, while the price of a new lighting installation is comparatively easy to establish, energy and maintenance costs are harder to gauge. For a correct calculation, though, it is important to consider not just acquisition costs but also expenditures on electricity and maintenance. In many cases, they account for more than three-quarters of total life cycle costs. Take street lighting, for example: if obsolete street lights with mercury vapour lamps are replaced by modern LED technology for lowered night-time lighting, electricity costs fall by as much as 80 percent.

Coupled with lower maintenance expenses, this means that the cost of refurbishment is quickly recouped. The same applies to

indoor lighting. The combination of efficient light generation and electronic control saves so much electricity that the money saved matches the initial outlay within only a few years.

Software facilitates calculation
How sustainably a lighting installation works can be worked out using special software. Many manufacturers offer calculation tools as free downloads. With them, different lighting designs can be compared, for example, in terms of their energy consumption, cost and carbon footprint. Designers and users can thus swiftly get a clear idea of the life-cycle costs and eco-balance of lighting products.

EPDs provide compact information
Additional information is furnished by Environmental Product Declarations (EPD) (see table). They are compact documents that report environmental impacts over the life cycle of a product, e.g. a luminaire.

Environmental Product Declaration (EPD) for a luminaire

Environmental Product Declarations (EPDs) provide a summary of all environmental impacts – e.g. consumption of primary energy, raw material acquisition – over the life cycle of the product. An EPD for a luminaire may contain the following information:

Produkt	Product description Characteristics Connected load ... Materials Types of material (e.g. steel, aluminium) Proportions by weight
Production	Place of manufacture Detailed list of manufacturing stages
Delivery	Delivery area Packaging Materials Weight
Use	Lifetime (in years) Service life (in hours) Energy mix (e.g. EU) Power rating (in watts) Total energy consumption (in kWh) Primary energy demand (in MJ) Special effects (e.g. thermal loading)
Recycling/ disposal	Details of recyclable components Details of proper disposal of non-recyclable components Proportion of recyclable materials by weight
Ökobilanz	Summary of all product-related environmental impacts over the full life cycle of the product, e.g.: use of energy (divided into renewable and non-renewable) water consumption global warming potential waste categories (non-hazardous, hazardous, radioactive)

Healthy workplace lighting makes good economic sense

Correctly planned, workplace lighting helps maintain employee health and wellbeing. Absenteeism is thus reduced and sick leave costs are lowered for the employer. The fact that investment in innovative lighting pays off can be seen from the highly simplified calculation on the right profiling health-promoting lighting for a 10 m² office workplace (observation period: ten years).

Cost of health-promoting lighting at a workplace (simplified example)		**Payroll cost of an employee**
Acquisition:	150 €/m2 × 10 m2 = 1,500 €	60,000 €/year1
Electricity:	260 kWh/year × 0.20 € × 10 = 520 €	
Maintenance:	50 €/year × 10 = 500 €	
Total:	2,520 €	600,000 €
	1 € per day	**0.50 € per minute**

[1] 250 work days, each eight hours (480 minutes) long
If an employee works more effectively for two minutes a day (rather than being unfocused or making mistakes), the cost of lighting for that day is recouped.

Lighting comfort and efficiency

Whether the focus is on office or street lighting, sustainable lighting design takes account of the full life cycle of a lighting installation. The aim is to maximise lighting comfort and minimise use of energy.

Sustainable lighting design looks at the entire life cycle of a lighting installation – from product selection to disposal. It is based on precise analysis: Which standards and regulations need to be observed? What opportunities are offered by the certification of buildings on the basis of sustainability criteria adopted for e.g. the American LEEED seal of approval? And very importantly: What are the users' needs? A lighting installation is only really sustainable if it is found useful in daily life. Hence the inclusion of scope for personalised control among the assessment criteria for green building certificates.

When a lighting installation is singled out for refurbishment, a clear description of its present condition is required to identify savings potentials and improvements in quality.

A truly sustainable lighting concept is more than just energy-efficient. It combines the principles of environmental protection, cost effectiveness and comfort. This means focusing on:

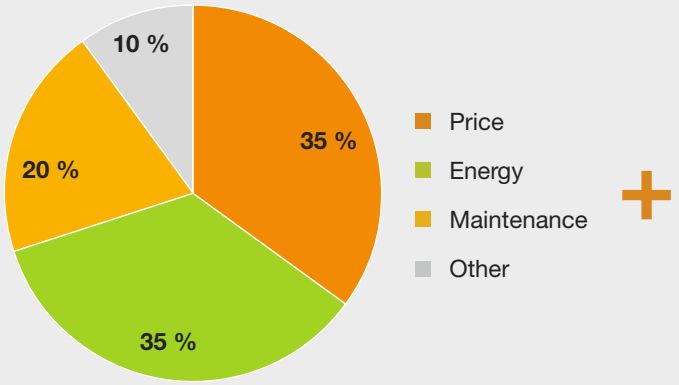
- recyclable, low-pollution products that present no disposal problems at the end of their life. Many manufacturers offer eco-labels or EPDs (Environmental Product Declaration) for customer guidance;
- energy-efficient long-life light sources, luminaires and operating devices, which keep power and maintenance expenses permanently low;
- replaceable components, which facilitate repairs and modernisation and extend a lighting installation's operating life; older LED modules, for example, can be replaced by new, higher-performance products;
- easy-to-operate switches and displays;
- high quality of light, which combines good visual conditions (visual quality) and agreeable atmosphere (emotional quality) with a positive impact on body and health (biological quality).

A whole range of "lighting tools" are available for achieving these goals.

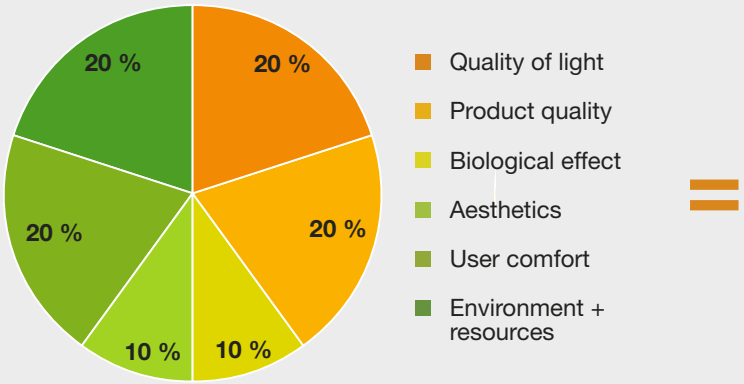
- Modern light sources such as LEDs or T16 fluorescent lamps reach 70 to 100 lm/watt luminous efficacy in operation. Very good colour rendering properties (R_a > 90) stand for a high quality of light.
- Luminaires with optimised reflector technology direct the light precisely onto the surfaces where it is required with minimal loss.

Example of a holistic lighting installation rating model

Economic lighting criteria (60 %)



Quality criteria (40 %)*



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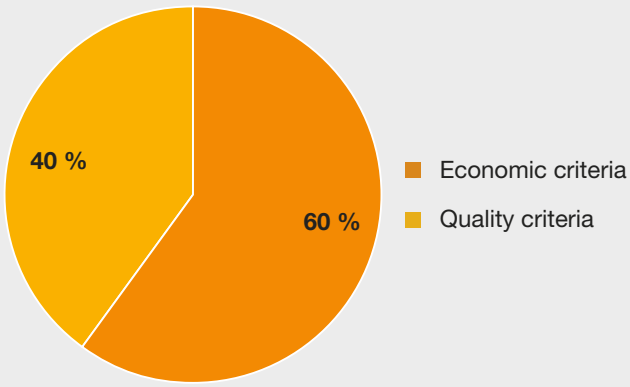
** Düsseldorf Higher Regional Court ruling: Quality may account for 50 % of a rating.*

21

Overall rating



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[20] Holistic lighting installation rating takes account of more than just financial aspects. Apart from economic selection criteria (e.g. investment and maintenance costs), it also assesses the quality of an installation, e.g. in terms of the quality of light and user comfort it delivers and the sustainability of the products used. According to a Düsseldorf Higher Regional Court ruling, quality features can account for 50 percent of a rating.

[21] Sustainable lighting combines high visual comfort with energy efficiency.

- Lighting management adjusts the lighting automatically to meet actual needs and enhances user comfort.
- Design software helps gear the lighting to actual requirements.

Only if the full potential of modern lighting technology is harnessed and usefully integrated can a lighting concept achieve good results. Intelligent lighting management plays a key role here. Where office luminaires are automatically switched by presence detectors, for instance, energy consumption decreases by 15 to 30 percent. Users also benefit from higher operating convenience: they do not need to activate the lighting themselves. However, one of the features of good lighting management is that users can change programmed lighting scenes as required at any time.

Cost effectiveness and financing
Lighting quality aside, designers and decision-makers also need to consider the cost effectiveness of an installation. It is important to note that energy and maintenance bills account for around 85 percent of total life-cycle cost; acquisition and installation make up only about 15 percent. So, an investment in energy-efficient, long-life lighting technology is quickly recouped – often within only a few years. What is more, the acquisition of environmentally friendly technology such as LED receives public support, e.g. in the form of government grants or favourable loans from the KfW banking group (see page 27).

Contracting permits early modernisation
Where a lighting installation requires modernisation, energy performance contracting (EPC) is a time-honoured model for financing the project. It allows refurbishment projects to be implemented promptly even when budgets are tight.

It works like this: a service provider modernises the lighting and subsequently profits from the costs thus saved. Depending on the project and contracting model, the payback period is eight to twelve years.

There are two different model contracts in EPC: the duration and the participation model. In the case of a duration model, the contractor normally receives the operating cost savings as remuneration for his services. For the client, this means a shorter contract period but no cost savings until it ends.

In the participation model, the contractor receives only a percentage of the operating

[22 + 23] Lighting management systems ensure that the right light is delivered at the right time. Daylight and presence control systems are particularly efficient.

[24] A sustainable lighting solution goes through several phases and passes through many hands in the course of its development. Effective interaction is vital to ensure that the end product, when it goes into operation, is energy-efficient and environmentally sound.

22

costs saved; the rest goes to the municipality. In this case, the client profits from immediate financial relief but accepts a longer contract period.

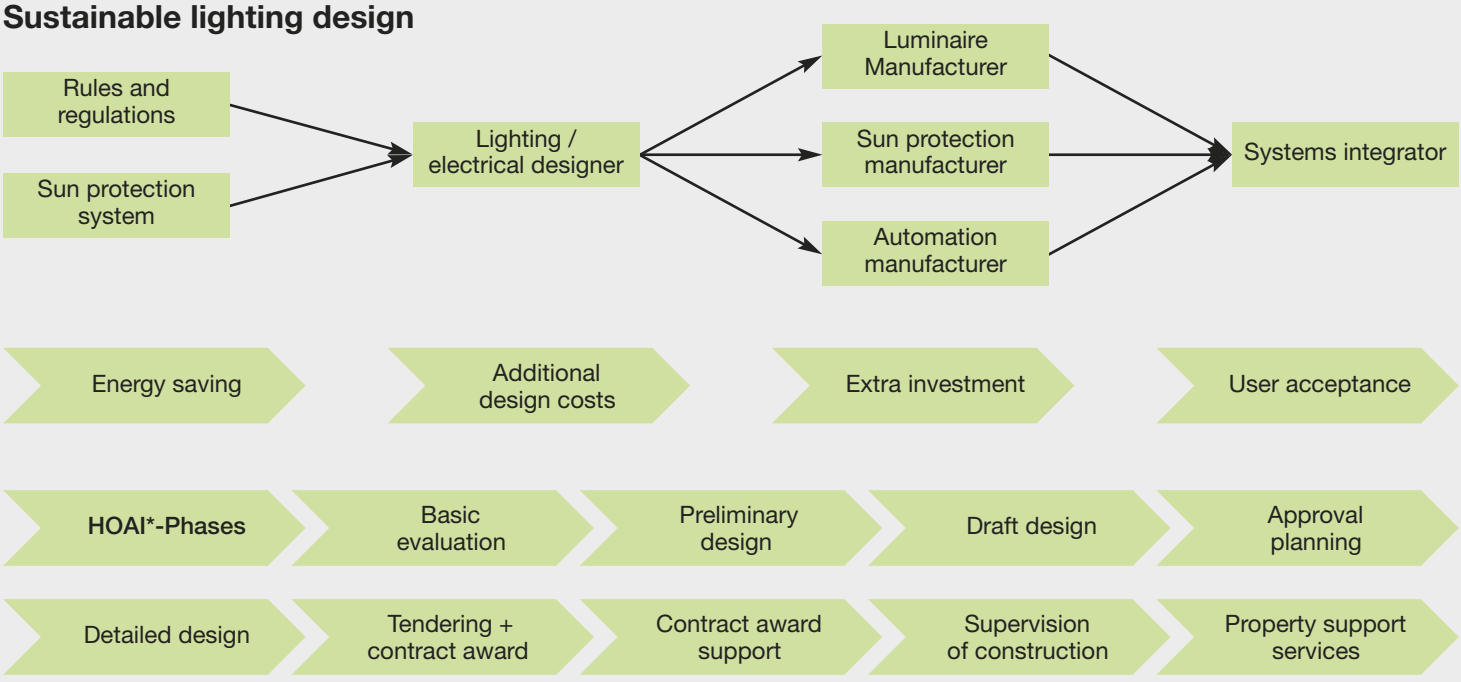
Maintenance and disposal
To work sustainably, lighting technology requires care, i.e. proper maintenance. For compliance with DIN EN 12464-1 “Lighting for indoor workplaces”, designers need to document how a lighting installation needs to be maintained (cleaning, lamp replacement).

In companies and municipalities, maintenance schedules specify when light sources and control systems need to be maintained. Maintenance is influenced by the degree of protection of the luminaire, operating conditions and other factors. For repairs, it is an advantage if defective parts are easy to replace. Environmentally friendly products can be almost wholly recycled after use. In the case of LED and fluorescent lamps, more than 90 percent of the material used is recyclable; recoverable materials nclude glass, metals, phosphor powders and mercury.

Many partners provide information on sustainable lighting design for lighting designers

23

Sustainable lighting design



HOAI* = Scale of fee for architects and engineers

24

and operators. One of them is the German Energy Agency (dena), which offers online tools for energy-efficient indoor and outdoor lighting (*www.lotse-innenbeleuchtung.de / www.lotse-strassenbeleuchtung.de*). At these sites, municipalities and companies find lots of practical tips and tools for every phase of a lighting project – from planning through to operation.

Indoor lighting:
Light for sustainable buildings
Building efficiency guidelines as well as standards and regulations on health and safety and consumer protection are important signposts for anyone preparing an indoor lighting concept. The German Energy Saving Directive (EnEV) also sets efficiency values for lighting in private and public buildings. The standard DIN EN 12464-1 on indoor workplace lighting contains detailed stipulations in terms of illuminance, glare limitation and other lighting quality features and requires adequate incident daylight and energy efficiency.

In some applications, the percentage of total energy consumption attributable to lighting is particularly high. In office buildings, it is around 50 percent, in hospitals 20 percent. Here, massive savings potential can be tapped by energy-conscious lighting. At a workplace, high quality of light has a positive effect on performance and wellbeing, while at the same time absenteeism declines. This has been confirmed by a number of studies (e.g. Mills/Tomkins/Schlangen, Journal of Circadian Rhythms, 2007).

Any energy-conscious lighting concept needs to be based on efficient light sources. The crucial factor, however, is the efficiency of the entire lighting system: luminaires with high light output ratios are optimally deployed if they direct light onto the surfaces where it is needed with only minimal losses. High-quality enclosures simultaneously guard against glare. Interaction with the architecture of the room is also important: light-coloured walls with good reflective properties ensure that little light output is lost.

Electronic control:
key to greater sustainability
Lighting management is the key to even greater sustainability in lighting. Without electronic control, there is no way that operators and users can harness all the advantages that modern light sources, luminaires and operating devices have to offer.

- Daylight sensors enable artificial lighting to be adjusted automatically according to the natural light available.
- Presence detectors and motion sensors activate lighting when a room or room zone is occupied. Timer control enables lighting to be automatically deactivated – an effective way to eliminate unnecessary burn time.
- Programmed lighting scenes enable lighting to be swiftly adjusted to meet changing requirements – a practical solution for offices, for instance, or restaurants.
- Control makes lighting dynamic; brightness and light colour can be infinitely varied. Positive stimuli can thus be generated for atmosphere and biorhythms. High illuminance and cool white light 'kick-start' our body in the morning; warm subdued light in the evening has a relaxing effect.

In existing buildings, additional energy savings could be achieved with lighting management. A study done by Braunschweig University of Technology in 2007 evaluating energy concepts for office buildings (EVA – Evaluierung von Energiekonzepten für Bürogebäude) showed that presence-dependent lighting control is still not used in many office buildings. It also indicated that further efficiency potential could be tapped by tailoring lighting more closely to requirements and thus avoiding unnecessarily high light outputs.

Lighting management systems such as DALI (Digital Addressable Lighting Interface) can be integrated via interfaces into higher-level building management systems such as KNX. Lighting thus becomes part of an efficient overall system along with other systems such as heating and ventilation.

Outdoor lighting:
efficient, low-maintenance and reliable
For the design of street lighting in Europe, the standard DIN EN 13201 sets out requirements for a wide range of application scenarios from small local access roads and parking areas to urban motorways and tunnels. Traffic volumes and the speed at

[25 – 27] Lighting solutions that are socially and environmentally sustainable also receive political backing: numerous incentive schemes for local government and business facilitate the financing of newbuild and refurbishment projects.

25

26

Financing and support

Sustainability is a political goal and is promoted accordingly. Among other things, the EU and the German government support newbuild and refurbishment projects that help mitigate climate change by increasing energy efficiency.

Incentives are also offered for energy-saving lighting projects, e.g. in local government or the private sector. Under the German environment ministry's National Climate Protection Initiative, for example, local authorities receive help when switching indoor or hall lighting to LED technology. The federal states have also set up schemes. In Baden-Württemberg, for instance, the "Klimaschutz-Plus" programme offers assistance for municipalities refurbishing indoor and street lighting. Information is available at *www.kommunen.klimaschutz.de/foerderung*.

Special loan programmes offered by the KfW banking group facilitate the financing of sustainable lighting projects. The KfW investment loan "Kommunen Premium – Energieeffiziente Stadtbeleuchtung", for example, is applicable for street or car-park lighting projects. If municipalities meet the technical requirements, eligible costs are financed up to 100 percent. *www.kfw.de*

Favourable financing options are also available through contracting. A service provider renews the lighting at his own expense and subsequently profits from the cost savings that are realised (information and contract texts available at *www.cfi21.org*. The Centre of Expertise for Contracting operated by the German Energy Agency (dena) offers initial consultancy sessions for local authorities seeking to make contracting arrangements for public buildings and puts them in touch with project development professionals. *www.kompetenzzentrum-contracting.de*

27

28

Best Practice: House of Knowledge Work

The “House of Knowledge Work” that opened in 2012 at the Fraunhofer Institute of Industrial Engineering (IAO) is a shining example of sustainable lighting design. At night, long rows of windows glow with light from indoors to give the building a stunning visual impact; during the day, they become generously dimensioned openings for natural daylight. Modern luminaire technology, LEDs and lighting management combine energy efficiency with good office working conditions. The building was awarded the LEED label of the US Green Building Council and a gold DGNB certificate for excellence in sustainable building.

which road users travel are among the factors considered here. Once luminaires have been selected, the required luminance is realised with as few light points as possible. But safety remains a top priority. And special attention is paid to conflict areas, such as crossroads or pedestrian crossings, where there is a heightened risk of collision.

Sustainable design is invariably based on wide column spacing and lowest possible wattage to keep electricity and maintenance costs low. Because of energy efficiency requirements, the only light sources capable of creating a truly sustainable solution are LEDs. Their low energy consumption produces the greatest cost saving and their longevity keeps maintenance costs low. What is more, LEDs are insensitive to cold and therefore particularly well suited for outdoor use.

Light makes for security

Energy efficiency and cost effectiveness are only one aspect of sustainability. At least as important is the need for municipal lighting to have the approval of residents and visitors. Lighting that uniformly illuminates roads and paths and thus ensures safety is in the public interest. At the same time, it creates an agreeable atmosphere in commercial and residential areas and avoids

Best Practice: Street lighting, Langen

The town of Langen near Bremerhaven is one of the first German municipalities to switch its street lighting completely to LED. It started with a successful pilot project, installing LED lighting in the town hall car-park. Switching the rest of the street lighting will cut energy consumption by around 62 percent and reduce CO2 emissions by some 473 metric tons a year. With additional savings on maintenance, the investment will be recouped in as little as around ten years. Thanks to modern control technology, the brightness of the lighting can be lowered late at night, whereas in the past the lighting along certain stretches of road was completely deactivated.

29

undesirable effects such as stray light on buildings or light pollution. Illuminated facades and signs facilitate orientation.

As well as high efficiency, LEDs offer the advantage of generating light that can be very precisely directed. Modern floods, spots and LED light lines can thus cast architecturally interesting buildings in the right light with virtually no light radiating into the night sky.

Additional savings potential can also be tapped in exterior lighting by lighting management. For example, street lights can be conveniently maintained by telemanagement. And when traffic volumes are low, luminous flux along arterial roads can be lowered – within the limits set out in standards – and thus adapted to actual requirements.

When existing installations are modified, structures that are already in place, such as power lines and buildings, impose major restrictions on lighting design. In many cases, a solution that meets the normative requirements needs to be found using existing light points. Intensity distribution curves are an important source of information for the designer. The data they provide forms the basis for selecting the best luminaire for the location. Other factors influencing how well the site is illuminated are the mounting height and angle of the luminaire head.

Sustainable procurement: Assessment matrix for cost-effective LED street lighting

Energy-efficient LED light sources are considered a truly sustainable solution for street and exterior lighting. LED technology is comparatively new and opens up totally new possibilities in lighting.

The range of products is growing fast – and public-sector clients often face the challenge of making informed judgements on the value for money that the products offer. At the same time, local authorities should not take price as the sole criterion for procurement decisions; all economic aspects need to be considered.

Help for sustainable procurement is provided by an assessment matrix developed as part of the German Government's LED Lead Market Initiative. This practical and easy-to-use Excel-based tool allows key economic evaluation criteria to be weighted and products compared in the procurement of LED street lights. Four main criteria are considered:

- price
- energy
- product quality and lighting characteristics
- aesthetic appeal

The matrix is designed for flexibility and can be adapted with little effort to meet individual requirements – both in terms of criteria and with regard to the default weighting assigned for individual rating aspects.

New lighting for old premises

Existing buildings can also be rendered sustainable – by refurbishment. New lighting saves energy, improves quality of light and helps premises meet legal requirements.

Flickering lamps, soiled luminaires, uniform monotonous room lighting – many offices, schools and administrative buildings still meet that description. In such cases, it would definitely be wrong to speak of sustainability because obsolete lighting installations consume too much electricity and burden the carbon balance. They cause high energy and maintenance costs and compromise the economic operation of a building. Users suffer from poor lighting conditions that make day-to-day work more difficult and can even give rise to health problems.

The good news is that it is not necessary to start again from scratch to enjoy efficient and ergonomic lighting. Carefully planned refurbishment lowers electricity and maintenance costs and at the same time delivers a better quality of light. In many cases, refurbishment is also needed to fulfil the strict legal requirements for energy efficiency. The German Energy Saving Directive (EnEV), for instance, regulates the maximum permissible overall energy demand of buildings. Lighting also impacts on the energy balance.

Combining components wisely

Whereas the lighting for a new building can be designed and optimised along with the building itself, refurbishment often involves taking account of special features of the existing building. Nevertheless, as a general rule, the individual components of a modern lighting system are readily combinable:

- Energy-saving light sources such as LEDs or modern fluorescent lamps are the basis of efficient lighting.
- Electronic ballasts (EBs) ensure that lamps and LEDs work efficiently.
- Optimised luminaires direct light where it is needed and avoid scattering losses.
- Electronic lighting management gears lighting to actual requirements.

The simplest form of refurbishment involves refitting existing luminaires with new, more efficient light sources. But mere replacement fails to tap the full potential of modern lighting technology. And the light distribution of the new light source is not always appropriate for the luminaire; in some cases, standard specifications may no longer be met.

It is worth ensuring that all components of a lighting installation work well together. The investment is quickly recouped through the electricity costs saved.

Lighting control – a lever for boosting efficiency

An important role here is played by electronic lighting control, which can be easily integrated in existing buildings. Lighting management systems such as DALI (Digital Addressable Lighting Interface) make a crucial difference in enabling a lighting installation to tap all efficiency potentials. In parts of a building that are only sporadically used, such as corridors and stairwells, lighting can be automatically deactivated by presence detectors. Lights are thus not in oper-

30

ation when they are not needed. Daylight sensors allow artificial lighting to be regulated according to the amount of natural incident light available. Constant light regulation - the so-called maintenance feature – dims luminaires to the maintained illuminance required and thus saves energy.

Example: Office refurbishment
The following example shows the potential of lighting control. Where obsolete office lighting with standard fluorescent lamps and conventional ballasts is replaced by modern light sources and electronic ballasts, energy consumption falls by around 55 percent. But if presence and daylight control systems are also used, the savings can be as much as 80 percent (see fig. 32). What is more, compliance with the ever stricter energy consumption limits that apply in the EU is virtually unachievable without electronic control.

The possibilities opened up by digital lighting control can be seen from a real-life example in the Baden-Württemberg city of Neckarsulm. Premises belonging to a German car maker there were fitted with new office lighting. The existing technology was completely replaced by recessed LED luminaires and LED downlights with a life expectancy of more than 50,000 hours. Presence and daylight control systems permit further energy savings of up to 50 percent.

But in any refurbishment project, whether it is for an office building, school or hospital, careful planning and analysis are the first step towards a lighting concept that meets all requirements in terms of efficiency and user comfort.

[30] Even in existing buildings, modern lighting technology makes for greater sustainability. Carefully planned refurbishment enhances lighting quality and lowers energy consumption.

[32] Replacing old lighting systems with modern lighting technology saves a great deal of energy and expense. Efficient installations with a lighting management system offer savings up to 80 percent.

Refurbishment checklist

Eight questions about the condition of your lighting installation	Yes?
Maintenance	
1. Have individual lamps failed?	
2. Are the luminaires soiled?	
3. Do lamps flicker when activated or in operation?	

→ *If the answer to any of the above questions is YES, you should clean the luminaires and replace faulty lamps.*

Refurbishment	
4. Is your lighting installation more than 15 years old?	
5. Is there too little light at your workplace?	
6. Do you feel dazzled when you are working?	
7. Do you see reflections or mirror images on your screen?	
8. Do you wish you had a way of switching or dimming the lighting?	

If the answer one of questions 4 to 8 is YES, you should check the lighting installation.

→ *If the answer to two or more of the questions is YES, it is time to think of refurbishment.*

→ *If you answered YES to all four questions, you should call a professional straight away and arrange for a refurbishment concept to be drawn up.*

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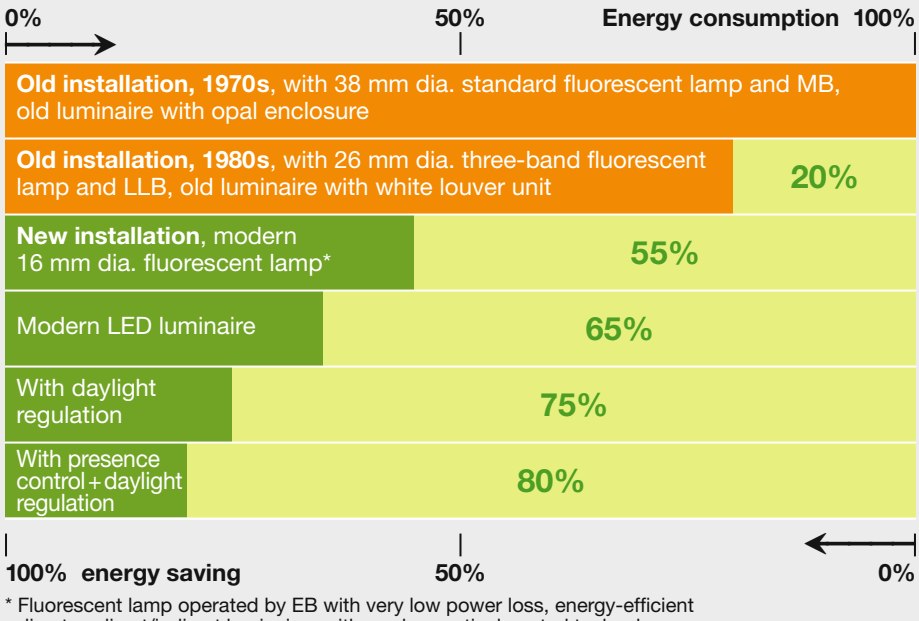
Savings potential of interior lighting



* Fluorescent lamp operated by EB with very low power loss, energy-efficient direct or direct/indirect luminaires with modern optical control technology

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Green light for technology

Efficient, durable, low-maintenance – sustainable lighting needs to meet a whole range of requirements. Crucially, light sources, luminaires and control system need to be perfectly coordinated.

In lighting technology, it pays to select quality products. A lighting installation only qualifies as “sustainable” if it operates efficiently and delivers a consistently high quality of light. What is more, users need to be able to tap the lighting’s full potential. Easy operation and user training help ensure that efficient lighting technology is used effectively.

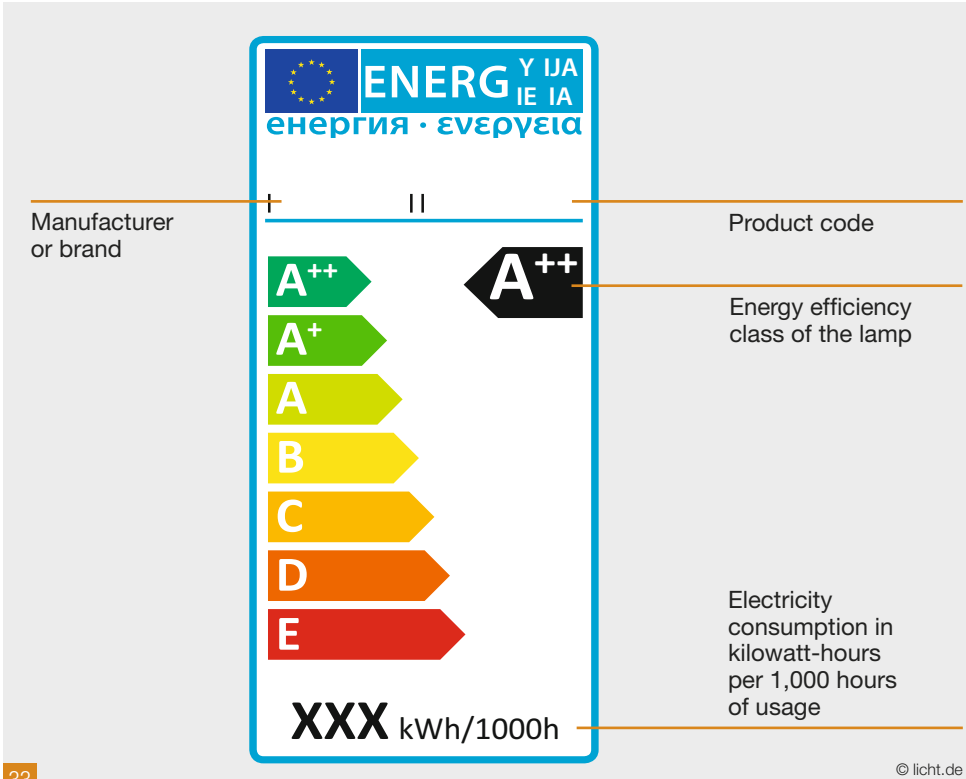
Lamps and LED modules

Efficient, long-life light sources are the basis for a sustainable lighting concept. The energy efficiency of a light source in operation is expressed by its luminous efficacy. This indicates how much input power is converted to light. Modern T16 fluorescent lamps, for example, reach a luminous efficacy of up to 100 lumen per watt. High pressure discharge lamps are also still in widespread use – for example in street lighting.

But it is LED technology – still a relative newcomer – that has the greatest development potential. In only a few years, it has made massive advances in luminous efficacy and longevity. In 2011 alone, LED efficiency surged by some 25 percent.

In the meantime, high-performance LEDs have a luminous efficacy of 100 to 120 lumen per watt in operation. They thus require 90 percent less electricity than an incandescent lamp. And thanks to their long life, virtually no maintenance is required. LEDs are very easy to control and therefore the best light source for electronic lighting management. They are also robust and insect-friendly – a light source could hardly be more sustainable.

LED lamps with a conventional screw or plug-in base make it easier for users to access the new technology. An 11W LED



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[33] The energy label for lamps (as of September 2013) shows details of a lamp’s energy efficiency class. LEDs and efficient energy-saving and fluorescent lamps are particularly economical in their use of electricity.

[34] With a wide range of light sources, the right choice can be made for every application.

lamp replaces a conventional 60W incandescent lamp without requiring the replacement of the existing luminaire. Better performance is achieved with complete LED modules incorporated in luminaires designed to cater for the specific characteristics of LED light sources.

The development or organic light-emitting diodes (OLEDs) also continues apace. The world's first planar light source, they are applied as a coating to either glass or plastic and open up a whole range of new applications. Above all, they allow light to be used directly, i.e. with no loss due to reflectors. The first marketable OLED luminaires have already been unveiled. Further advances in efficiency and longevity are anticipated.

The efficiency with which a light source operates is revealed by the energy label displayed on the packaging. It groups lamps and LEDS into energy efficiency classes and provides swift guidance for the purchase of lamps.

As of 1 September 2013, new efficiency classes were introduced by European directive EU 874/2012. They take account of the extra-low energy consumption of new light sources: energy-efficient LEDs qualify for the highest class (A++); incandescent lamps with reflector technology at best reach the lowest class (E). The new energy label also often shows the electricity consumption in kilowatt-hours per thousand operating hours.

Ballasts for greater efficiency

Discharge lamps and LEDs require additional technology to ensure smooth, energy saving operation. With fluorescent lamps in particular, the choice of ballast impacts on consumption and thus also on cost effectiveness.

Electronic ballasts (EBs) are particularly efficient. At the same time, they provide an interface for electronic lighting management and thus open up many possibilities for lighting design – from simple dimming to integration in higher-level building management systems that coordinate lighting with, say, heating and daylight management. The Energy Efficiency Index classifies ballasts according to their power consumption.

Luminaire selection

Design is not the only crucial factor to consider when selecting luminaires. It is equally important that the system as a whole – light source, optics, reflectors and any operating devices used – should work efficiently. Durability is assured by materials such as aluminium and high-quality coatings. At the same time, repairs should be possible and easy to perform. Precisely fitting enclosures prevent valuable light being absorbed by dirt and dust. Reliability is certified by marks of conformity such as "VDE", "GS" and "ENEC".

Luminaires that bounce some of their light off ceilings and walls are a popular choice for indoor lighting. The planar illumination they provide creates a bright, cheerful atmosphere and avoids glare. Light-coloured ceilings, walls and floors with high reflectance values are important here to ensure that as little light as possible is absorbed and thus lost.

Labels such as Environmental Product Declarations (EPD) provide guidance for luminaire selection. Among other things, they contain details of energy consumption, disposal requirements and life expectancy.

34


35


36

New luminaire design with LEDs
The LED has also transformed luminaire design. Because LEDs are so compact, luminaires require less material – so valuable resources are conserved and stylish new designs are possible. Large reflectors are no longer necessary because LEDs produce high-quality directional light which can be directed by optics straight onto the surface that needs to be illuminated. Owing to their small dimensions, LEDs for different light colours can be combined in a single luminaire, so light colour can be steplessly modified from warm to daylight white.

As with lamps, the efficiency of LED luminaires is measured in lumen per watt. Modern LED luminaires currently reach efficiency ratings of 90 lumen per watt and more. High temperatures damage LEDs and make them less efficient, so good thermal management is vital for a long life and problem-free operation. It ensures that the heat generated by LEDs in operation is swiftly dissipated.

Many technical characteristics of LED technology are gradually being standardised. The Zhaga initiative – an international consortium of lighting industry players – has been working on standard specifications since 2010. As a result, for example, obsolete LED modules can often be replaced by higher-performance models – another contribution to greater sustainability.

Lighting management – efficient and convenient
Controlling lights only from a switch is not very convenient and squanders opportunities to make additional energy savings. Intelligent lighting control has become the most important tool for achieving greater energy efficiency. Sustainable solutions are distinguished by the fact that they are easy to operate yet still offer every possibility for electronic control. The most important features are:

- dimming
- presence-dependent and/or timer-controlled switching
- daylight control
- lighting scene storage and retrieval
- maintenance and monitoring

Especially in rooms that are only sporadically used – corridors, conference rooms, toilets – presence-controlled lighting helps avoid unnecessary burn time. Sensors activate the lighting whenever a person enters the room and deactivate it again shortly after presence is no longer detected. Even more savings can be made with modern daylight management, which adjusts the artificial lighting according to the amount of natural incident light available. In conjunction with presence control, this technology cuts energy consumption by more than 50 percent. At the same time, the quality of lighting achieved is raised by the high daylight component.

Service for sustainable operation

Service is a key requirement if lighting is to operate sustainably. Manufacturers offer many services to ensure that users benefit from maximum efficiency and high lighting comfort. Experts from lighting industry companies provide advice at the design stage; service teams help commission lighting installations, address luminaires within a lighting management system or programme lighting scenes. And when a lighting installation is in operation, manufacturers help with technical issues and offer energy monitoring services to provide information about a lighting installation's power consumption.

37

In rooms with little incident daylight, dynamically changing lighting scenes can provide important cues for the human sleep/wake rhythm. High illuminance and cool light colours have a stimulating effect in the morning and help us through the dip in energy levels in the middle of the day. In the evening, warm white light and lower illuminance prepares the human body for sleep.

Planar light ceilings or ceilings illuminated from within the room create conditions similar to daylight. This makes for better stimulation of special photosensitive cells in the eye that help keep hormone levels balanced. A number of studies confirm the positive effects of biologically effective lighting, which is already being successfully used in offices, hospitals and schools.

Sustainable light for streets and squares

LEDs and electronic lighting control are also finding applications in street, square and path lighting. The savings potential is high: nearly a third of street lighting in Europe is estimated to be based on technology dating back to the 1960s. In Germany alone, modern lighting technology could cut the energy required for street lighting by around 2.2 billion kilowatt-hours (source: ZVEI).

In many municipalities, obsolete mercury or sodium vapour lamps have been replaced by modern systems. LEDs are finding increasing acceptance as an efficient alternative. Combining longevity with a high quality of light, they are also very robust. Another advantage: the light they produce has virtually no impact on insect behaviour.

Above all, however, LEDs are very suitable for electronic lighting management, which is also in increasingly widespread use in street lighting. Intelligent control can reduce brightness at times when traffic volume is low. Individual luminaires can be remotely monitored and thus more easily maintained. Controllable street lights can also be adjusted to changing weather conditions. In rain, for example, the light can be dimmed so that motorists are not dazzled. Conversely, more light than usual can be made available for major events.

With energy-saving LEDs and optics directing the light precisely onto the road surface, modern street lighting requires around 80 percent less electricity than obsolete mercury vapour technology. Wholly in line with the goal of sustainability, modern street lighting thus combines protection for the environment and cost effectiveness with comfort and safety.

[35 + 36] LEDs have conquered the realm of lighting. Extremely efficient and with a long life, easily controllable and available in many colours, they are the light source of choice for sustainable lighting.

[37] Lighting can be easily controlled via modern user interfaces, enabling programmed lighting atmospheres to be conveniently activated.

Glossary

AVV/EnEff – The general administrative regulation for procurement of energy efficient products and services needs to be observed by federal authorities. Among other things, it stipulates the efficiency requirements that need to be taken into account in specifications for tenders.

BREEAM – The BREEAM seal of approval (Building Research Establishment's Environmental Assessment Method) was introduced in 1990 and is one of the oldest green building certificates. The BREEAM seal is awarded by the independent Building Research Establishment BRE (UK).

Carbon Disclosure Project – A not-for-profit organisation established in London in 2000. Its mission is to motivate companies and local authorities to publish environmentally relevant information such as greenhouse gas emissions and water consumption figures.

Carbon footprint – Carbon footprint is the measure of the total CO_2 emissions caused by a product over its entire life cycle.

CE mark – The "CE" mark on products or product packaging is applied by manufacturers on their own responsibility to certify that their products meet the requirements of relevant EU directives. The CE mark is not a safety test symbol like the VDE, ENEC or GS mark.

Contracting – A form of financing that is frequently used by municipalities for the refurbishment of street lighting. Under a contracting agreement, a service provider renews the lighting at its own expense and then profits from the costs thus saved.

Council for Sustainable Development – The German Government created the Council for Sustainable Development (Rat für Nachhaltige Entwicklung) in 2001 to support the national sustainability strategy, develop concrete projects and champion the cause of sustainability in public.

DALI – The "Digital Addressable Lighting Interface" is a standardized digital interface for controlling electronic ballasts for light sources. DALI can be used to control individual luminaires, groups of luminaires or the lighting for entire rooms. Via gateways, DALI can be integrated in higher-level building management systems.

dena – The German Energy Agency (dena) was established in Berlin in 2000. It provides information on all matters relating to the efficient generation and use of energy.

DGNB – The German Sustainable Building Council (Deutsche Gesellschaft für Nachhaltiges Bauen e. V.) was established in 2007. Its mission is to promote sustainable building. Among other things, for example, the DGNB has developed a certification system that assesses new buildings and even entire urban districts in terms of their sustainability. Lighting is one of the aspects considered in assessments.

DIN EN 12464 – This is the most important standard for workplace lighting. Last revised in 2011, DIN EN 12464-1 sets out requirements for indoor workplace lighting.

EB – Electronic ballast for operating lamps. EBs have many advantages over conventional (CBs) and low-loss ballasts (LLBs): they heighten the luminous efficacy of the lamp, permit flicker-free starting, extend the lamp's life and automatically disconnect defective lamps.

Ecodesign Directive – EU Directive 2009/125/EC sets out requirements for the environmentally sound design of energy-related products. On the basis of the directive, inefficient appliances are gradually being phased out of the market. The general service incandescent lamp is a prominent example.

EEI – The Energy Efficiency Index (EEI) is used for classifying ballasts for light sources. The basis for classification is provided by the ballast directive 2000/55/EC.

ENEC – This is the European safety test mark for luminaires and other electrical products. It is awarded by independent test and certification institutes in Europe. In Germany this is VDE, which is identified by the testing agency number "10" beside the ENEC symbol. The acronym ENEC stands for European Norm Electrical Certification.

Energy Label –Standardised throughout the EU, the Energy Label provides information for consumers on the energy efficiency of electrical products. In 2013, a new Energy Label was introduced for light sources, assigning lamps and LEDs to seven energy efficiency classes. "A++" stands for very high and "E" for low energy efficiency. The Energy Label is normally found on product packaging.

EnEV – The German Energy Saving Directive (Energiesparverordnung – EnEV) implements the EPBD Directive at national level. Among other things, it requires energy performance certificates for private and non-residential buildings. For compliance with the EnEV, the primary energy requirement of lighting needs to be considered in the calculations.

EPBD – The EU directive 2010/31/EU (Energy Performance of Buildings Directive) sets out overall energy efficiency requirements for buildings.

EPD – Environmental Product Declarations (EPDs) summarise all of a product's environmental impacts – e.g. consumption of primary energy and raw materials.

ISO 9001 – The international standard of the International Organization for Standardization defines criteria for quality management. The aim is that products or services meet both consumer requirements and legal stipulations.

ISO 14001 – This international standard sets out criteria to be met by companies and other organisations for the creation of an environmental management system.

38

Among the elements of that system are the introduction and monitoring of environmental programmes. ISO 14001 is one of a family of standards; others in the series deal with further aspects of sound environmental management.

ISO 50001 – This standard provides guidelines for energy management systems that can help organisations steadily improve their energy efficiency. ISO 50001 contains stipulations relating to energy supply and consumption, measurement and documentation.

LED – The abbreviation stands for light emitting diode, which is an electronic semiconductor device that gives off red, green, yellow or blue light when an electric current is passed through it. White light can be obtained from blue LEDs by applying an internal luminescent coating. White light can also be obtained by colour mixing.

LEED – Green building certificate in widespread international use. The acronym stands for “Leadership in Energy and Environmental Design”. The LEED label is a quality mark for sustainable construction and is awarded in platinum, gold, silver and certified.

Light immissions – direct or indirect scattered light produced and radiated into the atmosphere by street, square or indoor lighting. In conurbations especially, this results in the creation of “light domes”, which dispel the natural darkness of night and can interfere with the biorhythms of wildlife.

LightingEurope – Association of the European lighting industry. LightingEurope was created at the end of 2012 by the amalgamation of CELMA (federation of national luminaire manufacturers associations) and ELC (European lamp companies federation). The association’s mission is to raise lighting system quality across Europe and worldwide.

Minergie – Swiss-based association that assesses buildings for sustainability. The Minergie label classifies buildings largely on the basis of their energy consumption. Minergie Eco also sets standards for health-promoting and eco-friendly construction.

OLED – Organic light emitting diodes. In contrast to LEDs, OLEDs incorporate an organic semiconductor material. The substrate used for the planar light sources is generally glass or plastic. The development of OLED technology is still at an early stage.

Packaging Directive –EU Directive 94/62/EC is designed to help avoid waste and promote the recycling and environmentally sound disposal of packaging. Companies that place packaged goods on the market are required to participate in systems for the return and disposal of used packagings.

REACH – EU Regulation 1907/2006 (Registration, Evaluation, Authorisation and Restriction of Chemicals) is an important pillar of EU legislation on chemicals. Among other things, its aim is to protect people and the environment from dangerous chemical substances. REACH obliges companies to assess and limit risks presented by chemicals.

RoHS – EU Directive 2011/65/EU (Restriction of Hazardous Substances) restricts the use of toxic substances such as lead or cadmium in electrical appliances and supports the use of substitutes.

WEEE – Among other things, EU Directive 2002/96/EC (Waste of Electrical and Electronic Equipment) provides the basis for the German Electrical and Electronic Equipment Act (ElektroG). It requires manufacturers to collect electrical waste and reuse it wherever possible.

Zhaga – This is a voluntary cooperative venture by international lighting manufacturers. Zhaga develops uniform standards for the physical, thermal and photometric interfaces of LED light engines. The aim, among other things, is to facilitate the replacement of LED modules made by different manufacturers.

ZVEI – German Electrical and Electronic Manufacturers’ Association (Zentralverband Elektrotechnik- und Elektronikindustrie e. V.). The ZVEI represents the interests of the German electrical industry as a whole and actively participates in international bodies and associations such as LightingEurope.

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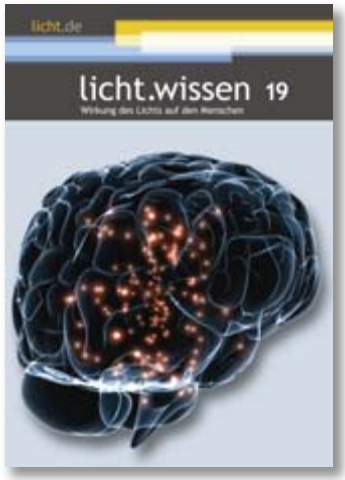

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licht.forum

licht.forum is a compact specialist periodical focusing on topical lighting issues and trends. It is published at irregular intervals.

www.licht.de

The industry initiative also presents its knowledge of lighting on the Internet. At www.licht.de, architects, designers, lighting engineers and end consumers have access to around 5,000 pages of practical tips, details of a host of lighting applications and up-to-the-minute information on light and lighting. An extensive database of product overviews provides a direct link to manufacturers.

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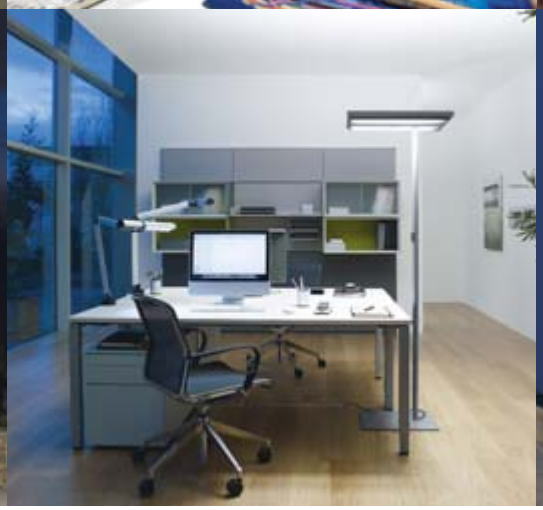

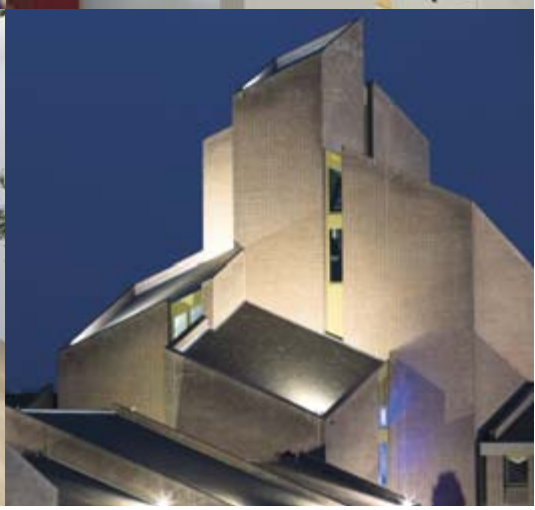

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